indices of refraction at different parts of the spectrum of substances possessing anomalous dispersion, and a discussion of the bearing of these observations on the theory of dispersion of light; experimental determinations, carried out with the greatest care, of the atomic weight of at least one element, the value of which is at present uncertain; a critical discussion of the theories of flight and of the experimental researches which form the base of such a discussion; a theoretical and experimental examination of the causes of the deviations from Ostwald's dilution law; exact direct measurements of the osmotic pressure of solutions, not showing electrolytic dissociation, especially in view of the determination of the limit of concentration at which the deviations from the laws of Boyle and Gay-Lussac begin to be felt; a research on the origin and physiological signification of the green colouring matter in the bodies of articulated green animals; an experimental research on the electrolytic dissociation of substances dissolved in different mixtures of water and alcohol; a determination of the diminution of the vapour pressure of solutions in water of the chlorides of sodium, potassium, calcium, and magnesium between the temperatures 0° C. and 100° C. for at least six different concentrations, the molecular conductivity, the lowering of the freezing point, and the rise in the boiling point are to be determined for the same solutions, the whole to be discussed from the point of view of the theory of Arrhenius and the criticisms of Kahlenberg; a quantitative research on the radiation of two simple gases in a magnetic field; new quantitative determinations on the distribution of radium in the earth's crust; a study, as complete as possible, of the structure and development of one species of the genus Trypanosoma, *Tr. lewisi* for preference.

The gold medal of the society (or its value) is offered for the best paper received in answer to one of these questions. Replies should be written in Dutch, French, English, German, or Latin, not signed by the author, but bearing a motto, accompanied by a sealed letter containing the same motto and the author's name, and addressed to Dr. G. J. W. Bremer, the secretary of the society, at Rotterdam, before February 1, 1910.

PAPERS AND REPORTS ON INSECTS.

BULLETIN No. 3 of the Sleeping Sickness Bureau is devoted to the life-history of the tsetse-fly, *Glossina palpalis*, a species which appears to have been originally obtained in Sierra Leone, but is now known to have a very wide distribution, including Angola, Nigeria, the Congo State, the lake region, the Egyptian Sudan, Uganda, and north-eastern Rhodesia. After referring to the peculiar mode of propagation of tsetses, the author discusses the influence of external conditions on the distribution and numbers of the species under consideration, referring particularly to shade, altitude, season, temperature and humidity, forest, water, and food-supply.

A number of new species and one new genus of American mosquitoes are described by Messrs. H. C. Dyar and F. Knab in vol. lii. of the Smithsonian Miscellaneous Collections, as a preliminary to a monograph now in course of preparation by Dr. L. O. Howard and the authors of this paper. The new genus, Dinanamesus, is allied to Dinocerites, from which it differs by a reduction in the length of the second joint of the antennæ.

In the report of the entomologist of the U.S. Department of Agriculture for 1908, Dr. L. O. Howard refers to the work done during the year in connection with the Mexican cotton-boll weevil, a species which continues to inflict much damage on growing cotton. It has been found that parasites are year by year becoming much more effective in controlling the ravages of this weevil, a fact promising favourable results in the efforts of the Bureau to encourage and spread the former. During the season under review the average parasitism is shown to have been doubled in Texas and trebled in Louisiana. Special attention was also directed during the year to insects injurious to forests, and it is satisfactory to learn that the efforts of private owners and the forest officials to check and control the alarming outbreaks of the Black Hills beetle in the neighbourhood of Palmer Lakes and Colorado

Springs, as well as in the adjoining Pikes Peak National Forest, have proved a complete success.

The whole of vol. xxxi., No. 1, of Notes from the Leyden Museum is devoted to a monograph, by Dr. H. W. van der Weele, on the Mecoptera (scorpion-flies) and Planipennia of " Insulinde." The latter name is taken to denote the Dutch colonies in the Malay and Papuan archipelagoes, but the paper, which is illustrated by five plates, includes descriptions of species from those parts of Borneo and New Guinea which do not belong to Holland. A number of new species and subspecies, and three new genera, are named and described in the course of the paper, while some interesting particulars are given with regard to the life-history of one of the species of " antlion " (Myrmeleon).

EXPLOSIVE COMBUSTION, WITH SPECIAL REFERENCE TO THAT OF HYDRO-CARBONS.[1]

IT is hardly necessary to remind you that the subject of my discourse will be ever associated with the illustrious name of Davy. Davy turned his attention to the phenomena of flame in the year 1815, in response to an urgent appeal on the part of a committee formed in the north of England, to investigate the causes of accidents arising from the explosion of fire-damp in coal mines, and to devise means for their prevention. The perennial interest of his researches, however, lies not so much in their immediate practical success, great as this undoubtedly was, as in the broader theoretical issues which were disclosed, and brought within the region of experimental inquiry, by so splendid an exercise of genius.

Davy insisted on the necessity of considering flames in all cases " as the combustion of an *explosive mixture* of inflammable gas, or vapour, and air," and he defined flame as " aëriform, or gaseous matter, heated to such a degree as to be luminous." For the starting and propagation of a flame in an explosive mixture, he showed that each successive layer of gas must be raised to a certain definite temperature, called the " ignition point," and he investigated both the ignition temperatures and the explosion limits of a large number of the commoner combustible gases. He then proceeded to his famous discovery that, notwithstanding the extremely high temperatures of flames, which, in the case of cyanogen, he estimated to be " above 5000° of Fahrenheit," they can be readily extinguished by contact with a cooling surface of sufficient area and heat-conducting power, and that for this purpose metal surfaces are by far the most efficient. How he developed and applied this discovery to the construction of his " safe-lamp " for miners is a matter of history.

In experimenting upon the ignition temperatures of explosive mixtures, Davy made the important observation that combustible gases combine with oxygen at lower temperatures without any appearance of flame whatever. He emphasised the importance of a complete investigation of the chemical aspects of this flameless combustion, and he himself was led to ask whether, seeing that the temperatures of flames far exceed those at which solids become incandescent, a metallic wire can be raised to incandescence by the slow combustion of two gases " without actual flame, but producing heat enough to keep the wire ignited." In this way he discovered the remarkable property of platinum and other metallic wires of inducing surface combustion, and in the course of his further experiments on this subject he made two notable observations respecting the burning of compounds containing carbon and hydrogen. He found " much carbonic oxide " produced when a platinum wire was kept incandescent by the slow combustion of a mixture of ethylene and oxygen, rendered non-explosive by an excess of the hydrocarbon and in a similar experiment with ether vapour he recorded the appearance of " a pale phosphorescent light " accompanied by " the formation of a peculiar acrid volatile substance possessed of acid properties."

Finally, in speculating upon the difficult and thorny subject of the luminosity of hydrocarbon flames, he was

[1] Abridged from a discourse delivered at the Royal Institution on Friday, February 28, 1908, by Prof. W. A. Bone, F.R.S..

" led to imagine " that it " might be owing to the *decomposition* of part of the gas towards the interior of the flame where the air was in smallest quantity, and the deposition of solid charcoal, which, first by its *ignition* and afterwards by its *combustion*, increased in a high degree the intensity of the light." It is important to observe that not only did Davy rightly attribute the luminosity of a hydrocarbon flame to the presence therein of incandescent carbon, but also that he avoided the error of attributing the separation of carbon to a supposed preferential burning of hydrogen.

In considering the propagation of a flame through an explosive mixture of gases, it is necessary to distinguish between two well-defined conditions. When such a mixture is ignited, the flame travels for a certain limited distance (a few feet only) at a fairly uniform slow velocity, which in the case of a mixture of hydrogen and oxygen in their combining ratios is approximately 34 metres (38 yards) per second. This initial stage of the combustion is called " *inflammation.* "

After traversing a few feet, however, the flame begins to vibrate, and alters in· character. The vibrations become more and more intense, the flame swinging backwards and forwards with oscillations of increasing amplitude. Then one or other of two things happens ; either the flame is extinguished, or it goes forward with an exceedingly great and constant velocity, producing the most violent effects. The new condition thus set up is termed " *detonation,* " and the forward movement of the flame is called the " *explosion wave.* "

The discovery of " *detonation* " in gaseous mixtures was made simultaneously by M. Berthelot and MM. Malard and Le Chatelier in the year 1881 ; Berthelot proved that the velocity of the explosion wave is independent of the length of the column of gas traversed, and that for the same gaseous mixture under given physical conditions it always has a constant value. In this connection I must mention Prof. H. B. Dixon's exhaustive researches on the " *rates of explosion* " of gaseous mixtures, which have extended in so many ways our knowledge of explosive combustion.

Experiment I —Perhaps the best illustration of the outward difference between ordinary " *inflammation* " and " *detonation* " is afforded by the case of a mixture of carbonic oxide and oxygen in their combining ratios. When ignited in an open tube 4 or 5 inches long, the mixture burns quietly with the familiar blue flame. Far otherwise is it, however, when a long column of the mixture is fired in a leaden coil, where the brief initial period of *inflammation* is succeeded by the *explosion wave*, which dashes onwards through the gases at a rate of 1700 metres (about a mile) per second with shattering effect.

Another notable feature of " *detonation* " is the extremely short duration of the flame. In the course of some experiments carried out under Prof. Dixon's direction, it was found that the duration of luminosity in each successive layer of gas in the detonation of electrolytic gas does not exceed 1/5000th part of a second ; but, short as this time is, it is something like a million times longer than the interval between successive molecular collisions in a gaseous mixture.

The question of how a hydrocarbon burns, that is to say, precisely how it is attacked by the oxygen, has been the subject of much discussion during the past fifteen years. The main points in dispute may be conveniently summarised under three heads.

(1) During the greater part of last century the belief prevailed that the hydrogen is much the more combustible of the two elements of a hydrocarbon, and that consequently when combustion occurs in a limited supply of oxygen, the hydrogen is preferentially burnt, as follows :—

$$C_2H_4 + O_2 = 2C + 2H_2O.$$
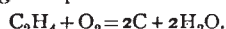
Who was the author of this view, or what was originally its experimental basis, is not quite clear, but it received the active support of two such eminent authorities as Thomas Graham and Michael Faraday, and for fifty years it was regarded as one of the most certain articles

of chemical faith. It was finally overthrown by Dixon and Smithells in the year 1892.

(2) The second theory originated with Kersten in 1861, who, as the outcome of experiments on the explosion of a mixture of ethylene and electrolytic gas, asserted that " before any portion of the hydrogen is burnt, all the carbon is burnt to carbonic oxide, and that the excess of oxygen then divides itself between the carbonic oxide and the hydrogen." In other words, Kersten attempted to substitute the idea of the preferential burning of carbon for that of the preferential burning of hydrogen. His views, however, received no serious attention until they were revived by Dixon and Smithells.

The chief experimental basis for this theory is the behaviour of ethylene and acetylene when exploded with their own volume of oxygen. More than a century ago Dalton found that a mixture of equal volumes of ethylene and oxygen yields mainly carbonic oxide and hydrogen on explosion, without any separation of carbon, in conformity with the equation

$$C_2H_4 + O_2 = 2CO + 2H_2$$
1 vol. 1 vol. 2 vols. 2 vols.
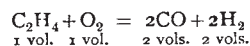
This fact, after being overlooked for nearly eighty years, was re-discovered by Dixon in 1891 ; moreover, a few years later, when it was proved that acetylene behaves in a precisely similar manner,

$$C_2H_2 + O_2 = 2CO + H_2.$$
1 vol. 1 vol. 2 vols. 1 vol.
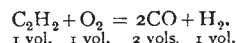
the advocates of the theory were able to claim a considerable body of evidence in support of their case.

(3) But the idea of a " *preferential* " combustion, whether of carbon or of hydrogen, seemed repugnant to well-established principles concerning the nature and conditions of chemical interactions in gaseous systems. Moreover, whilst the assumption of a *direct* passage from an initial system of ethylene and oxygen, $C_2H_4 + O_2$, to the system carbonic oxide and hydrogen, $2CO + 2H_2$, implied a simple transaction from the kinetic standpoint, an extension of the idea to the case of such a hydrocarbon as propylene,

$$2C_3H_6 + 3O_2 = 6CO + 6H_2,$$
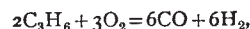
would at once raise serious difficulties.

It therefore remained to consider whether the solution of the problem might not lie in the assumption of an initial *association* of the hydrocarbon and oxygen forming an unstable " oxygenated " molecule, which subsequently rapidly decomposes. Thus, for example, the changes involved in the explosive combustion of an equimolecular mixture of ethylene and oxygen might conceivably be represented somewhat as follows :—

$$C_2H_4 + O_2 = [C_2H_4O_2] = 2CO + 2H_2$$
unstable
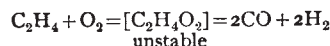
Many years ago, indeed, Prof. H. E. Armstrong suggested that the combustion of a hydrocarbon takes place under the conjoint influence of water and oxygen, and involves the successive formation of intermediate " *hydroxylated* " molecules, which at high temperatures rapidly decompose into simpler products. Little notice was taken of his suggestion at the time, but recent researches have shown that " *hydroxylated* " molecules are probably formed, even in flames, although I think it doubtful whether water vapour is an essential factor in the process.

The researches recently carried out at the Manchester University have covered the entire range of conditions under which hydrocarbons can be burned, from the slow, flameless combustion discovered by Davy right up to the extreme conditions of detonation. An exhaustive study of the slow combustion of methane, ethane, ethylene, and acetylene, at temperatures between 250° C. and 400° C., afforded decisive evidence against the preferential burning, whether of carbon or of hydrogen. Large quantities of aldehydic intermediate products were isolated, and the balance of evidence was decidedly in favour of the " *hydroxylation* " theory, with the proviso, however, that the oxygen is directly active.

With the extension of the research to the conditions existing in hydrocarbon flames and explosions, it became increasingly evident that the mechanism of combustion is essentially the same above as below the ignition point. I do not mean, of course, that the phenomena observed at low temperatures, in slow combustion, are exactly reproduced in flames, but rather that the result of the initial molecular encounter between the hydrocarbon and oxygen is probably much the same in the two cases, namely, the formation of an "oxygenated" molecule. At the higher temperatures of flames, secondary thermal decompositions undoubtedly come into operation at an earlier stage, and play a more important *rôle* than in slow combustion, but they do not precede the onslaught of the oxygen upon the hydrocarbon, but arise in consequence of it.

Having thus explained the main issues, I propose to perform a series of experiments on the explosive combustion of acetylene, ethylene, and ethane, some of which are crucial as regards the rival theories under discussion.

Experiment II.—I have here three cylindrical bulbs of stout borosilicate glass (capacity=about 60 c.c.), fitted with firing wires, hermetically sealed, and containing respectively equimolecular mixtures of each of the three hydrocarbons with oxygen, that is to say, mixtures corresponding to $C_2H_2+O_2$, $C_2H_4+O_2$, and $C_2H_6+O_2$, respectively.

Now, according to the theory of the preferential combustion of carbon, these mixtures should on explosion yield nothing but carbonic oxide and hydrogen, without any separation of carbon or formation of steam, as follows :—

p_2/p_1*

(a) $C_2H_2+O_2=2CO+H_2$ 1.5
(b) $C_2H_4+O_2=2CO+2H_2$ 2.0
(c) $C_2H_6+O_2=2CO+3H_2$ 2.5

* The symbols p_1 and p_2, used in this and subsequent tables, denote the initial and final pressures of the *cold* original mixture and gaseous products (dry) at constant volume and at the same temperature.

On firing the mixtures, it is at once evident that something very like this does happen in the cases of (a) and (b). There is absolutely no deposition of carbon, and no appreciable condensation of steam in the cold products. Far otherwise is it, however, in the case of the bulb containing the mixture $C_2H_6+O_2$. A lurid flame fills the vessel, accompanied by a black cloud of carbon particles, and a close inspection of the cold bulb will reveal a considerable condensation of water. The pressure ratio p_2/p_1 is approximately 1.5, and an analysis of the gaseous products would prove the presence of about 10 per cent. of methane. The bulb will now be opened, rinsed out with water, and the formation of aldehydic products demonstrated by means of Schiff's reagent. It is clear that these results are wholly inconsistent with the theory of the preferential burning of carbon.

Did time permit, I could easily demonstrate to you by other similar experiments that the *outward* difference here revealed between the burning of ethylene and that of ethane extends to all the other gaseous olefines and paraffins; that is to say, whereas mixtures of olefines and oxygen corresponding to $C_nH_{2n}+\fra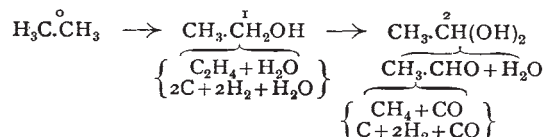c{n}{2}O_2$ on explosion yield mainly carbonic oxide and hydrogen, without separation of carbon, mixtures of paraffin and oxygen corresponding to $C_nH_{2n+2}+\frac{n}{2}O_2$ yield carbon, oxides of carbon, methane, hydrogen, and steam, all in considerable quantities. Are we then to conclude that there is some peculiarity about the constitution of an olefine which induces a preferential burning of its carbon, whilst the corresponding paraffin is burnt in an entirely different way? The following experiment will show that such a view cannot for a moment be entertained.

Experiment III.—I will now fire a bulb containing a mixture of 60 per cent. of ethylene and 40 per cent. of oxygen (*i.e.* $3C_2H_4+2O_2$). As might be expected, the flame is accompanied by a large deposition of carbon, but what is of greater importance still is the fact that a considerable amount of water is also formed. The full significance of this experiment may be gathered from the following data :—

Original ($C_2H_4=59.65$ per cent. $p_1=562$mm. $p_2/p_1=1.45$
mixture ($O_2=40.35$,, $p_2=816$,,
Gaseous ($CO_3=2.5$, $CO=37.2$, $C_2H_2+C_2H_4=6.4$, $CH_4=6.5$,
products ($H_2=47.4$ per cent.

	C	H	O
Units in original mixture ...	670 ...	670 ...	227
Units in gaseous products ...	482 ...	572 ...	172
Difference	188 ...	98 ...	55

I think it will be now admitted that such an experiment as this completely destroys the foundations of the theory of the preferential burning of carbon. As I have already stated, the original experimental basis of the theory was the behaviour of an equimolecular mixture of ethylene and oxygen, yet here is proof that on closer examination the behaviour of ethylene is inconsistent with the theory, which must, therefore, be abandoned.

Experiment IV.—The next experiment is designed to illustrate the infinitely greater affinity of acetylene and ethylene as compared with that of hydrogen for oxygen at the high temperatures of flames. I have here two bulbs containing mixtures of each of these hydrocarbons with hydrogen and oxygen corresponding to $C_2H_2+2H_2+O_2$ and $C_2H_4+H_2+O_2$ respectively, and I will ask you to contrast the behaviour of these with that of the equimolecular mixture of ethane and oxygen, $C_2H_6+O_2$, which was exploded a few minutes ago. It should be noted that whilst all three mixtures contain the same relative proportions of carbon, hydrogen, and oxygen, they differ in respect of the proportions between the combined carbon and hydrogen. Asking you to bear in mind how the equimolecular mixture of ethane and oxygen on explosion gave rise to a black cloud of carbon and a considerable formation of water, I will now fire the other two mixtures. You will observe that in neither case has there been any deposition of carbon, and an inspection of the cold bulbs will show that little or no steam formation has occurred. In fact, the hydrocarbon has been burnt to carbonic oxide and hydrogen, leaving the hydrogen absolutely untouched by the oxygen.

These experiments have an important bearing on the chemistry of flames. Hydrogen is usually considered as one of the most combustible of gases, but here we see it pushed to one side by the all-powerful hydrocarbon as though it were so much inert nitrogen. This at once raises another question which has lately been occupying my attention. Ever since Davy's experiments on flame, the combustibility of hydrogen has been considered to be superior to that of methane; this, however, cannot be true in regard to slow combustion, for it can be easily proved that between 300° C. and 400° C. methane is oxidised at a far faster rate than hydrogen[1] in the absence of surfaces, such as platinum or palladium, which readily occlude hydrogen.

It does not, I think, impose too great a strain on the imagination to picture the probable mechanism of combustion in hydrocarbon flames, and for this purpose ethylene and ethane may be taken as typical examples. It may be assumed that the affinity of a hydrocarbon for oxygen is so great at high temperatures that the initial stage of its combustion takes precedence of all other chemical phenomena in flames. This is probably true of the propagation of flame through explosive mixtures of hydrocarbons and oxygen. In the special case of a stream of a hydrocarbon burning in air, partial decomposition may occur in the innermost regions of the flame, where the supply of oxygen is very limited, before combustion begins; but, in general, whenever the hydrocarbon and oxygen are brought together at high temperatures, their mutual affinities will prove superior to any disruptive forces which would otherwise break down the hydrocarbon. It is probably not so much the original hydrocarbon as its hydroxylated molecule which decomposes in flames; the sudden increase in the internal energy of the hydrocarbon molecule, consequent upon its initial association with oxygen, would render the resulting hydroxylated molecule extremely unstable, and in default of its immediate further oxidation, it would

[1] Since the above was written, it has been proved experimentally that even in explosive combustion at high initial pressures the affinity of methane greatly exceeds that of hydrogen for oxygen

speedily decompose. The explosive combustion of ethylene may, therefore, be represented by the following scheme :—

$$H_2C\overset{o}{:}CH_2 \longrightarrow HO.CH\overset{1}{:}CH_2 \longrightarrow HO.CH\overset{2}{:}CH.OH$$

$$\overbrace{\begin{cases} C_2H_2+H_2O \\ 2C+H_2+H_2O \end{cases}} \quad \overbrace{2CH_2O = 2CO+2H_2}$$

In a sufficient supply of oxygen, the transition from the original hydrocarbon to the dihydroxy state is probably so rapid that no breaking down of the ethylenic structure occurs in passing through the initial monohydroxy stage. Indeed, it is conceivable that under the extreme conditions of detonation the passage from o to 2 may be effected in a single molecular impact. The dihydroxy derivative would at once break down into carbon monoxide and hydrogen, via formaldehyde.

But when the oxygen supply is reduced below the equimolecular proportion, it is evident that the initial monohydroxy derivative cannot all be oxidised to the dihydroxy stage; some of it would, therefore, decompose partly into acetylene and steam and partly also into carbon, hydrogen, and steam, together with some methane.

In a similar manner the combustion of ethane would involve the rapid passage through ethyl alcohol to acetaldehyde, and steam, with subsequent decomposition of the aldehyde into carbon, hydrogen, methane, and carbonic oxide, with the proviso that a reduction of the oxygen supply below the equimolecular proportion would bring about in some measure the decomposition of the alcohol into ethylene and steam, &c., at stage 1.

$$H_3C\overset{o}{.}CH_3 \longrightarrow CH_3.\overset{1}{CH_2OH} \longrightarrow CH_3.\overset{2}{CH(OH)_2}$$

$$\overbrace{\begin{cases} C_2H_4+H_2O \\ 2C+2H_2+H_2O \end{cases}} \quad \overbrace{CH_3.CHO+H_2O}$$
$$\overbrace{\begin{cases} CH_4+CO \\ C+2H_2+CO \end{cases}}$$

But the cases of ethane and ethylene are typical of all other hydrocarbons, so that it may be said that, in general, the mechanism of explosive combustion involves (1) the initial formation and subsequent decomposition of hydroxylated (or " oxygenated ") molecules; (2) in a sufficient supply of oxygen, the independent oxidation of the decomposition products; (3) in an insufficient oxygen supply, the subsequent breaking down of unsaturated hydrocarbons, interactions between carbon and steam, or between oxides of carbon, hydrogen, and steam, the final system depending on the amount of available oxygen, the temperature of the flame, and the rate of cooling.

Experiment V.—The influence of different rates of cooling of the flame on the final system may be illustrated by firing an equimolecular mixture of ethane and oxygen in two glass vessels having approximately the same volume but widely different surface areas. For this purpose I have selected (1) a tube about 1 metre long and 2 cm. internal diameter, and (2) a globe of 8.5 cm. internal diameter. Both these vessels have the same volume (about 300 c.c.), but the surface area of the tube is very nearly three times that of the globe. It is therefore to be expected that, in consequence of the more rapid cooling of the flame, there will be a greater accumulation of the primary combustion products in the case of the tube experiment. On comparing the results of the two explosions, it is at once evident that more water and less carbon have been produced in the case of the tube; moreover, the pressure ratio p_2/p_1 is 1.45, as compared with about 1.75 in the globe experiment, and an examination of the products would show that the lower ratio is accounted for by the much greater survival of acetylene, ethylene, and aldehydic products in the tube experiment. These facts, which are set forth in the following table, are in complete harmony with the hydroxylation theory.

Experiment VI.—The experiments I have so far shown you refer more particularly to the initial period of " inflammation " in explosive combustion, that is to say, to the conditions ordinarily prevailing in hydrocarbon flames. The question may be asked whether or not the views I have advanced are applicable to the extreme conditions of " detonation " or of explosions under high initial pressures. This question can best be answered by a consideration of

the behaviour of an equimolecular mixture of ethane and oxygen under these extreme conditions.

Inflammation of an Equimolecular Mixture of Ethane and Oxygen.

		A In Long Tube		B In Large Globe	
p_1 p_2 p_2/p_1		701 mm. 1018 ,, 1.45		685 mm. 1187 ,, 1.73	
% Composition of Gaseous Products	CO_2 CO C_2H_2 C_2H_4 CH_4 H_2	4.20 34.80 5.00 2.65 8.85 44.50 }7.65	}	3.40 36.10 0.15 7.25 53.05	

	C	H	O	C	H	O
Original mixture .	694	1041	354	678	1017	346
Gaseous products	643	738	220	558	805	255
Difference . .	51	303	134	120	212	91
% Difference .	7.6	29	37.8	18	20	27.5

It is difficult to set up detonation in this mixture; the gases must be fired at an initial pressure of about 1½ atmospheres in a stout leaden coil of about 1-inch internal diameter. Even then it is necessary to start the explosion wave in a special firing piece containing electrolytic gas under pressure. I therefore regret that, owing to the special arrangements requisite for success, it is not possible to make the experiment to-night. I will, however, carry out an experiment on the explosion of the gases at an initial pressure of 15 atmospheres.

The cylindrical steel bomb on the table is part of an apparatus recently installed in the fuel and metallurgical laboratories of the University of Leeds for investigations on gaseous explosions under high pressures. The bomb is about a foot long with an external diameter of 4 inches, and the central cylindrical explosion chamber is 8 inches long by 1 inch in diameter. It has been tested by hydraulic pressure up to 1000 atmospheres, and has been repeatedly used for experiments with mixtures of hydrocarbons and oxygen at initial pressures of as much as 40 atmospheres. The bomb is now connected, through a valve at the top, with a standard Bourdon gauge, and contains an equimolecular mixture of ethane and oxygen at a pressure of 15.8 atmospheres. The valve will now be closed, and the mixture fired by means of an electrical arrangement in the special firing piece.

All that is audible of the explosion is a sharp click, and on opening the valve connecting with the gauge again the final pressure of the cold products of explosion is recorded. After applying the necessary correction for the " dead space " in the gauge connections, the final " corrected " pressure is as nearly as possible 30.8 atmospheres, corresponding to a ratio $p_2/p_1 = 1.93$. I would now direct your attention to the tabulated results of a similar bomb experiment carried out a few weeks ago at Leeds at an initial pressure of 25 atmospheres, and also at the same time to those of another experiment in which the gases were detonated in a lead coil at an initial pressure of 1½ atmospheres.

In both these experiments carbon was deposited, and it is evident also that steam was formed. The ratio p_2/p_1 was as nearly as possible 2.0 instead of the 2.5 required by the theory of the preferential combustion of carbon. Moreover, a notable feature of the results is the presence of as much as 7 per cent. of methane among the products of the experiment at 25 atmospheres; the fact that so much methane survived when all other hydrocarbons were battered to pieces during the explosion (no traces of either acetylene or ethylene being found in the products) is a remarkable testimony to its relatively great stability at the

highest temperatures of explosion flames. There is no evidence in these experiments of any real discontinuity between the chemical phenomena of ordinary "*inflammation*" and those of "*detonation.*" The higher temperatures and more violent conditions in "*detonation*" are responsible for the more complete breaking down of unsaturated hydrocarbons and a greater "unburning" of steam by carbon, but there is probably no difference as regards the mode in which the hydrocarbon is attacked by the oxygen in the two cases.

Results of Explosion of an Equimolecular Mixture of Ethane and Oxygen under High Pressures.

—	A Detonation in Lead Coil	B Explosion in Steel Bomb
p_1	1180 mm.	25·2 atms.
p_2	2240 ,,	51·7 ,,
p_2/p_1	1·90	2·05
% Composition of Gaseous Products CO_2	1·80	2·6
CO	39·10	37·2
C_2H_2	0·90 ⎫ 1·40	nil
C_2H_4	0·50 ⎭	
CH_4	7·70	7·0
H_2	50·00	52·2

	C	H	O	C	H	O
Original mixture.	1186	1779	587 mm.	25·35	38·0	12·55 atms.
Gaseous products	1151	1507	488 ,,	24·50	34·6	11·05 ,,
Difference . .	35	272	99 ,,	0·85	3·4	1·5
% Difference .	3	15	17	3·4	9	12·0

I therefore believe that, so far as our present knowledge goes, the views I have put forward afford a simple and consistent interpretation of hydrocarbon combustion, whether it be the slow flameless kind discovered by Davy or the more complex phenomena of ordinary flames so wonderfully expounded by him, or, finally, the extreme conditions of temperature and pressure characteristic of the explosion wave.

SUPPLEMENTARY LIST OF FORTHCOMING BOOKS OF SCIENCE.

I N addition to the books referred to in NATURE of last week, the following works are announced:—

ANTHROPOLOGY.

G. Fischer (Jena).—Die palaolithischen Funde von Taubach in den Museen zu Jena und Weimar, Dr. G. Eichhorn, illustrated. *Hodder and Stoughton.*—New Impressions of Primitive Man, E. Clodd; The British Race, J. Munro. *Elliot Stock.*—Folk Lore and Folk Stories of Wales, M. Trevelyan, with introduction by E. S. Hartland; Indian Folk Tales, E. M. Gordon (cheap edition).

BIOLOGY.

W. Engelmann (Leipzig).—Geschichte der biologischen Theorien, Prof. E. Radl, 2 Teil; Der Vegetation der Erde, xi. Band, Die Vegetationsverhältnisse der Balkanländer, Prof. L. Adamović, illustrated; xii. Band, Botanical Survey of the United States of North America, Prof. J. W Harshberger, illustrated; Prantls Lehrbuch der Botanik, new edition, illustrated; Vorträge und Aufsätze über Entwicklungsmechanik der Organismen, edited by Prof. W. Roux, vi. Heft, Über chemische Beeinflussung der Organismen durch einander, Prof. E. Küster; vii. Heft, Der Restitutionsreiz, Dr. H. Driesch. *G. Fischer (Jena).* —Recueil des Travaux botaniques Néerlandais, publié par la Société botanique Néerlandaise, vol. iv., illustrated; Histologische Beiträge, Prof. E. Strasburger, Heft vii., illustrated; Zoologisches Wörterbuch, edited by Prof. H. E. Ziegler, Lief. iii. *Hodder and Stoughton.*—Germ Life:

Bacteria, H. W. Conn. *T. Werner Laurie.*—The Garden Booklets:—The Rose Garden; The Rock Garden; The Bulb Garden; The Formal Garden; The Water Garden; The Fern Garden. *G. Philip and Son, Ltd.*—School Gardening, W. E. Watkins and A. Sowman.

GEOGRAPHY AND TRAVEL.

Hodder and Stoughton.—Camps and Cruises of an Ornithologist, F. M. Chapman, illustrated; The Story of Geographical Discovery, J. Jacob. *Hutchinson and Co.*— The American Egypt: a Record of a Sojourn in Yucatan and other Parts of Mexico, C. Arnold and F. J. Frost, illustrated. *G. Philip and Son, Ltd.*—A Guide to Geographical Books and Appliances, J. F. Unstead and N. E. MacMunn, edited by A. J. Herbertson; A Rational Geography, E. Young, part ii.; Our Own Islands, H. J. Mackinder; and a new edition of L'Estrange's Junior Course of Comparative Geography, revised and entirely rearranged, with maps in black and white.

GEOLOGY.

W. Engelmann (Leipzig).—Das Salz, dessen Vorkommen und Verwertung in sämtlichen Staaten der Erde, Dr. J. Buschman, 2 vols.

MATHEMATICAL AND PHYSICAL SCIENCE.

W. Engelmann (Leipzig).—Tafeln für Maschinenrechnen, Prof. O. Lohse. *Harper Brothers.*—The Ether of Space, Sir Oliver J. Lodge, F.R.S. *T. Werner Laurie.*—Everyday Electricity, F. Broadbent, illustrated; Everyday Astronomy, H. P. Hollis, illustrated. *T. Murby and Co.*—Hobbs's Electrical Measurements (new edition). *G. Philip and Son, Ltd.*—Practical Elementary Science, T. Samuel and H. Foxcroft, three parts; A Handy Book of the Stars, Captain W. B. Whall (new edition). *S. Rentell and Co., Ltd.*—New editions of the Telegraphist's Guide; The Telegraphist's and Telephonist's Notebook; and Questions and Solutions in Telegraphy and Telephony: being Solutions to the Questions set by the City and Guilds of London Institute in the Ordinary Grades of Telegraphy and Telephony for the Years 1904–8, H. P. Few.

MEDICAL SCIENCE.

W. Engelmann (Leipzig).—Die aphasischen Symptome und ihre corticale Lokalisation, Dr. N. von Mayendorf, illustrated; Die basedowsche Krankheit, Prof. H. Sattler, 1 Teil, Symptomatologie, illustrated; Anleitung zur Präparation und zum Studium der Anatomie des Gehirns, Dr. E. Villiger. *G. Fischer (Jena).*—Handbuch der Anatomie des Menschen, Erster Band, Skeletlehre, illustrated; Ländliche Hygiene, Dr. E. Roth, Zwanzigster Band.

TECHNOLOGY.

W. Engelmann (Leipzig).—Die Gasmaschinen, A. von Jhering, in 2 Teilen, 2 Teil, Geschichtliche Entwicklung und Beschreibung der Gasmaschinen, illustrated; Vorlesungen über Ingenieurwissenschaften, Prof. G. Mehrtens, 1 Teil, Statik der Baukonstruktionen und Festigkeitslehre, Erster Band, illustrated (new edition).

MISCELLANEOUS.

W. Engelmann (Leipzig).—Die mnemischen Empfindungen in ihren Beziehungen zu den Originalempfindungen, Prof. R. Semon (Mneme, ii. Band). *Hodder and Stoughton.*—Thought and Feeling, F. Ryland.—The St. Bride's Press, Ltd.—Lectures on Sanitation, W. D. Scott-Moncrieff; The Polar Planimeter: How it is Used and How it Operates, F. J. Gray.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

CAMBRIDGE.—An exhibition of 50l. a year, tenable for two years, is offered by the governing body of Emmanuel College to an advanced student commencing residence at Cambridge as a member of Emmanuel College in October. The exhibition will be awarded at the beginning of October.

LONDON.—The governors of the Imperial College of Science have decided to purchase a section of freehold property in Cornwall giving free access to a mine for the